



DIVISION OF USX CORPORATION

FINAL NPDES PERMIT
MN 0057207
MINNTAC TAILINGS BASIN AREA
MT. IRON, MINNESOTA

HYDROGEOLOGIC REPORT

NOVEMBER 30, 1987

AIRIAL VIEW - MINNTAC TAILINGS BASIN
November 4, 1985



AERIAL VIEW - MINNTAC TAILINGS BASIN
November 4, 1985

INTRODUCTION

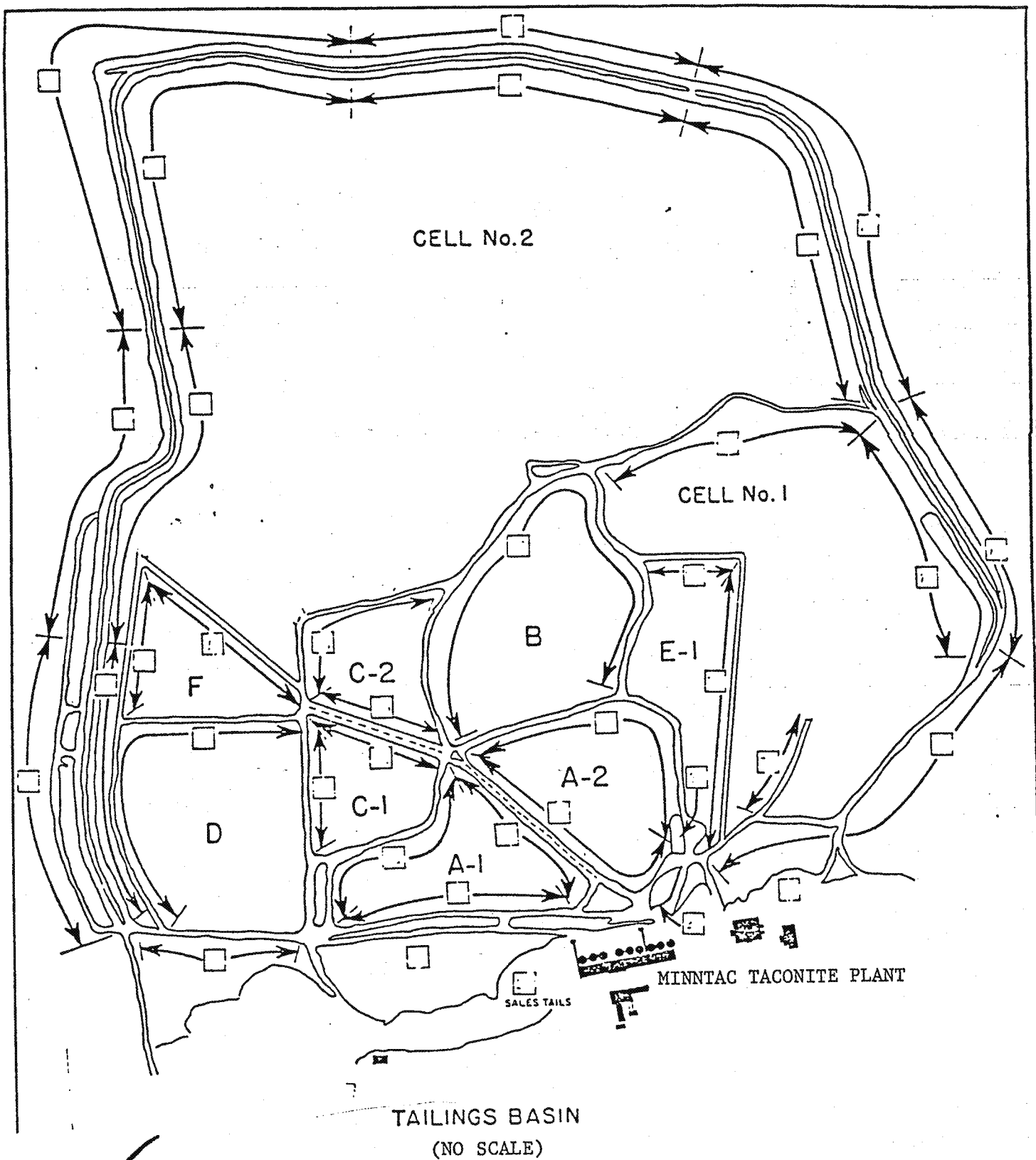
The Minntac Tailings Basin serves to store fine and coarse tails waste from the taconite process and to provide a source of make-up water for the taconite plant processing operations. The entire area of the tailings basin, 8,972 acres, is enclosed on three sides, along approximately 48,000 feet of perimeter, by an impervious core dam and on the fourth side, along the remaining 24,000 feet of perimeter, by original high ground.

Within the tailings basin are several intermediate or inner cells constructed to contain the fine tailings and to direct the over-flow water to the clear water cell for return pumping to the plant site. Evapo-transpiration, seepage, and product loss are the only water losses from the system at present. Each 100 tons of taconite ore processed produces approximately 28 tons of coarse tails and 42 tons of fine tails.

LOCATION

The basin is located approximately 2.5 miles north and west of the city of Mt. Iron, St. Louis County, Minnesota. The area is north and adjacent to the USX Corporation, Division USS, Minntac Taconite Plant. The basin is shown on the United States Department of the Interior Geological Survey Quadrangle Maps of Virginia, Minnesota and Kinney, Minnesota.

The Minntac Tailings Basin is situated entirely within Township 59 North, Range 18 West. It includes all or part of Sections: 3-10 inclusive; 15-22 inclusive; 28-30 inclusive.



PREVIOUS HYDROGEOLOGIC INVESTIGATIONS

Minntac personnel conducted a complete investigation of the property. Stream gauging was originated, in the early 1950's, on the major streams leaving the property. Water quality was assessed. These surveys have continued to the present. A sizeable file of stream flows and water quality are in the hydrology files at Minntac. Flow records for Dark River were published in USGS annual publications up until 1979. Detailed soil sample logs were made of all materials within the basin. Many test holes were extended down and into the bedrock. The underlying rock was sampled with a diamond bit drill. Drill cores were described by staff geologists. The important diamond drill cores are on file in the Minntac Core Shed.

It was concluded, at an early date, that there were no major structural difficulties in the bedrock of the basin area. The Giants Range Granite was sound and impervious to water flow. In the northwest and southeast corners of the basin, there is bedrock composed of the Ely Greenstone. The contact between the two rock types is sound.

The basin and nearby lands are completely owned by Minnesota Ore Operations of the USX Corporation. The reliability and completeness of the above described information is more than sufficient to provide the basin operators with information concerning the safe operation of the facility.

The following discussions and Exhibits record these facts.

BEDROCK GEOLOGY

The Laurentian Divide of the Mesabi Range forms the general south limit of the disposal basin. The divide trends north 73 degrees east and rises some 1195 feet above Lake Superior and 323 feet above the 872 foot mean elevation of the bedrock floor of the basin.

The divide known locally as the Giants Range is composed on the east by the Ely Greenstone Formation, the oldest bedrock in the area. The greenstone is a dense, blackish, dark green meta-basalt and meta-volcanics containing mafic flows with interbedded volcanic tuff beds. Lying unconformably on this ancient greenstone is a great, unknown thickness of Knife Lake Formation. These meta-sediments are composed of steeply dipping (up to 90 degrees) greatly deformed, dark graywackes, quartzites and sandstones to siltstones. Interbedded in these 2.8 billion year old rocks are meta-volcanics and included tuff beds.

This mass of Pre-Cambrian country rock has been so badly metamorphosed that classification of whether it is Ely Formation or Knife Lake Formation is difficult to impossible.

Both formations are well jointed but the void openings to water flow are at a minimum.

Intruded into these old, Pre-Cambrian country rocks is a younger, pink, quartz-feldspar-biotite granite of approximately 2.7 billion years in age. The massive, Giants Range, Algoman Granite (see Exhibit V, Page 11) forms steep and generally sharp contacts with the older enclosing rocks. Narrow, granitic dikes intrude and cross rocks adjacent to the granite. Tectonic disturbances after granite emplacement has produced several sets of tight joints.

Is it safe to
assume that the granite
was banded GW?

In the south-east one quarter of Section 28, Township 59 North, Range 18 West, there is a steep angled, nearly north-south fault that has cut off the meta-volcanic-meta-sediment country rocks on the west; and the pink, Algoman Granite west of this fault forms all of the core and highlands of the Laurentian Divide.

The massive, pink feldspar granite forms the tight, impervious bedrock floor under the glacial and post-glacial sediments of much of the Minntac Tailings Basin and accounts for 71 percent of the basin.

Two areas of the basin are underlain by the Ely Greenstone Formation. Some 180 acres in the southeast corner of the basin are composed of this bedrock and a 325 acre tract in the northwest corner is also composed of the same meta-volcanics. The Ely Formation forms approximately 29 percent of the underlying bedrock of the Minntac Tailings Basin.

Eighty-two roller bit/diamond core drill holes have penetrated the thin cover of glacial and post-glacial sediments which overly the basin bedrock. See Exhibits III (Map-Bedrock Elevations, back) and VI (Table-Soils Drilling, Page 13).

Based on a study of samples from these drill holes, several statements can be made concerning the rock floor of the basin:

- A. The general trend of nearly all the shallow bedrock depressions is east to west.
- ? B. The bedrock slopes approaching the divide on the south tend to be at right angles to the divide.
- C. The basin has the form of one, wide, shallow east to west valley into which are incised several minor east to west trending depressions.

- D. One wide depression (8000 foot) on the north, enclosed by the 860 foot contour is separated from a centrally positioned, narrow (1500 to 2000 foot) east to west depression by a narrow 7 to 35 foot ridge. See Exhibit III (back).

Division of the basin into four approximately equal areas gives the following data (all elevations are Lake Superior datum):

- E. Northeast 1/4:
Mean bedrock elevation is 854 feet with a standard deviation of 19.5 feet.
- F. Northwest 1/4:
Mean bedrock elevation is 846 feet with a standard deviation of 14.9 feet.
- G. Southwest 1/4:
Mean bedrock elevation is 885 feet with a standard deviation of 24.8 feet.
- H. Southeast 1/4:
Mean bedrock elevation is 903.6 feet with a standard deviation of 26.4 feet.
- I. All the diamond drill core recovered was fresh and with good core recovery.
- J. Finally, no areas showing permeable bedrock were indicated by any of the eighty-two test drill holes.

EXPLORATION

One hundred and fifty-two (152) drill holes were constructed on the alignment of the perimeter dikes. The holes sampled surface materials with a 2" outside diameter split tube. Approximately 80 drill holes extended down to, or into the bedrock. Drill core from the latter holes were examined and given geologic descriptions. Each drill site was tested by "Standard Penetration Test" which recorded penetration, in inches, of a steel rod, after it was hit with a 140-pound hammer.

Ten groundwater observation wells were completed in 1981. Well No. 6 penetrated into bedrock.

In addition to the above drilling, hundreds of hand augured, Buda drilled and hand penetration tests were made within the basin. This original work is on file in the Mining Engineering and Hydrology Departments at Minntac. See Exhibits III, IV, VII (Maps, back), VI (Table, Page 13), and X (Well Logs, Page 23).

SURFICIAL GEOLOGY AND TOPOGRAPHY

The basin is located upon Pleistocene glacial deposits and post-glacial peats comprising sediments typical of a sandy, outwash plain. Scattered across the basin are isolated clay-boulder knolls. These knolls are underlain with unstratified deposits of boulders and coarse gravel.

The sands, silty sands and gravels were carried from the glacier by meltwaters. The deposits are typically sorted into discontinuous and interfingering beds of stratified drift. The topography is generally flat, only slightly masking the gently rolling underlying bedrock.

The texture and grain size of the glacial deposits indicates, in general terms, the relative distance from the glacial face at the time of deposition. Much of the lower deposits are coarse and well washed indicating relative closeness to the debris-laden melting ice. Probable readvances of the glacier into the outwash introduced boulder piles. Some of the abundant lower deposits of smaller boulders were probably ice-rafted to their final resting place.

The melting ice front had receded some distance from the outwash plain when the upper, silty deposits were laid down to cap the lower, well washed beds.

Minor glacial and post-glacial streams reworked the deposits into local, typical stream bed deposits. Abandoned shallow glacial lakes are now found filled with swampy peat beds. Lake shorelines are composed of peat mixed with all varieties of glacial outwash material and ice-rafted boulders.

With the exception of the clay-boulder knolls and the lowest boulder piles, the sediments are well, to very well washed, thus producing a high rate of water permeability.

Some 100 to 200 roller-bit drill holes were drilled into the basin's unconsolidated sediments. See Exhibits VI (Table, Page 13) and VII (Map, Back). Depths of less than 10 feet to over 55 feet were recorded and the materials logged.

Subdivision of the basin into four approximately equal divisions give the following statistics:

NORTHEAST 1/4:

Mean soil depth is	17.1 feet
Standard deviation is	11.0 feet

NORTHWEST 1/4:

Mean soil depth is	15.6 feet
Standard deviation is	6.3 feet

SOUTHWEST 1/4:

Mean soil depth is	14.3 feet
Standard deviation is	9.2 feet

SOUTHEAST 1/4:

Mean soil depth is	9.1 feet
Standard deviation is	4.9 feet

The mean soil depth of the basin is	14.0 feet.
The standard deviation of the basin is	7.85 feet.

A contour map of the tailings basin soil depths shows east to west structures following the general trend of the underlying bedrock. Two deeper channels, greater than 40 foot depth, lie side by side. The channel on the north shows north and north-west appendages. The second channel, occupying a central position in the basin, underlies a former, pre-basin river bed. Observation Wells numbered 4, 5, and 6 sample the former channel. Wells numbered 1, 2, 3, and 7 sample the latter, or old stream bed channel.

A north to south cross section (see Exhibit VIII, Back) was constructed through the basin which accurately describes the drilled sediments and their relationship with the bedrock floor. Thirty-eight test drill holes used in the section construction are typical of all the drill holes on record. It is therefore assumed that the types and percentages of materials found within these drill holes are related to the basin as a whole.

Thirty-five sediment types are recognized in the cross section. Five major formations, as related to the entire basin, are as follows:

Sand formation	62.74%
Boulder formation	17.31%
Clay formation	8.50%
Gravel formation	5.97%
Peat formation	<u>5.52%</u>
	100.00%

The thirty-five soil types, as recognized in drill hole samples, are recorded as the following example:

CLAY, sand, gravel and boulders

The sample indicates a clay type (type underlined) with lesser amounts of sand, gravel, and boulders.

The following table defines the thirty-five soil types and their percentage abundance in the basin as a whole:

TAILINGS BASIN SEDIMENTS

<u>DESCRIPTION</u>	<u>PERCENT (%)</u>
<u>SAND</u> and gravel	16.99
Silty, fine <u>SAND</u>	10.13
<u>BOULDERS</u> and gravel	7.45
Fine <u>SAND</u> and gravel	6.86
<u>PEAT</u>	4.77
<u>SAND</u>	4.02
Medium <u>SAND</u>	3.87
Silty <u>SAND</u> and gravel	3.87
<u>BOULDERS</u> , sand and gravel	3.58
<u>SAND</u> , gravel and boulders	3.43
Silty <u>CLAY</u>	2.98
Coarse <u>SAND</u> and gravel	2.83
<u>BOULDER</u>	2.09
<u>BOULDERS</u> and fine sand	2.09
<u>CLAY</u>	2.09
Coarse <u>GRAVEL</u> and sand	2.09
Silty <u>SAND</u> and clay	2.09
<u>GRAVEL</u> and boulders	1.94
Fine to medium <u>SAND</u>	1.94
<u>GRAVEL</u>	1.79
Silty fine <u>SAND</u> and boulders	1.64
<u>BOULDERS</u> , gravel and clay	1.49
<u>SAND</u> and clay	1.49
<u>SAND</u> and boulders	1.34
<u>CLAY</u> , sand, gravel and boulders	0.89
Silty <u>CLAY</u> and boulders	0.89
Coarse <u>SAND</u>	0.89
<u>CLAY</u> and gravel	0.75
<u>CLAY</u> and sand	0.75
<u>PEAT</u> , sand and boulders	0.75
Silty <u>SAND</u> , gravel and boulders	0.75
<u>BOULDERS</u> , clay and sand	0.61
Coarse <u>SAND</u> and boulders	0.60
<u>CLAY</u> and boulders	0.15
<u>GRAVEL</u> and fine sand	0.15
	<u>100.00</u>

HYDROGEOLOGIC REPORTS OF SURROUNDING LANDS

Lands surrounding the presently constructed basin are not entirely controlled by USX Corporation. Interest is nevertheless shown about conditions in these lands. No explorations are available nor has the Corporation plans for near-future field work.

Published reports covering these areas can be consulted:

1. Preliminary Surficial Geologic Map of the Mesabi-Vermilion Iron Range Area Northeastern Minnesota, by R. D. Cotter, H. L. Young, and T. C. Winter.
Miscellaneous Geologic Investigations Map I-403
United States Geological Survey and Minnesota IRRR
Published in 1964.

This report indicates "pitted outwash plain" in the area of the present basin and "silty, brown till" surrounding the basin.

2. Quaternary Geology of Minnesota and Parts of Adjacent States
Professional Paper 161
United States Department of the Interior
Published in 1932

This report indicates the surface formations in the immediate area of the basin and that of the immediate surrounding lands to be the same. "Rolling to gently undulating deposits laid down at border of ice sheet; composition variable, ranging from very stony and sandy material to heavy clay with few stones..."

3. Geology of Minnesota, A Centennial Volume
P. K. Sims and G. B. Morey, Editors
Published by the Minnesota Geological Survey
Published in 1972

This report describes bedrock geology in the vicinity of the Minntac tailings basin and the surrounding lands.

4. Ground and Surface Water in the Mesabi and Vermilion Iron Range Area Northeastern Minnesota, by R. D. Cotter, H. L. Young, L. R. Petri, and C. H. Prior
Geological Survey Water Supply
Paper 1759-A
Published Washington 1965

A map in the rear pocket of Report Number 4 shows the location of surface water Gauging Station #1310. This report is meaningful for water flow records of the Dark River prior to tailings basin construction.

A review of the published material would indicate the immediately surrounding lands to be generally described and identical with the previously described hydrological conditions of the basin.

HYDROGEOLOGIC DESCRIPTION OF THE TAILINGS BASIN

Prior to basin construction, the area was drained by two exit systems. The Dark River and its tributaries accounted for nearly 95% of the drainage. The Dark River flows west and northwest to Dark Lake.

The Sand River system flows north and east to Little Sandy Lake and beyond into Sandy Lake.

The extremely shallow soils of the basin area provide very little recharge to either stream system except during periods of heavy rain fall and during the spring snow melt. The abundant glacial melt water washed sands and gravels provide ready flow channels through sub-surface water zones. These water bearing zones are controlled by the near vicinity of the glacially polished bedrock.

The gradient of all major stream channels would be described as low. The water flow is generally sluggish. Minor steeper gradient tributaries flow north off the Laurentian Divide towards the two river systems. These latter tributaries are usually dry except during periods of heavy rainfall.

Construction of the Minntac Tailings Basin has eliminated the headwater positions for the natural river systems. The basin has effectively reduced the stored water source by less than 25% of the total available for stream recharge, under pre-construction conditions.

Of the total annual average precipitation of 27.30 inches, approximately 40% or 10.92 inches occurs as surface runoff; the remainder is lost to ground water, evaporation, and transpiration.

INSTALLATION OF GROUND WATER MONITORING OBSERVATION WELLS
IN THE VICINITY OF THE MINNTAC TAILINGS BASIN, MT. IRON, MINNESOTA

The ten borings were drilled with a truck-mounted all-terrain CME-750 drill rig between July 22 and August 5, 1981. The borings were initially advanced using continuous flight solid and hollow stem augers to identify either perched water or the hydrostatic ground water table. Casing and bentonite drilling fluid were then used to support the hole open while drilling. Borings were drilled to depths of 21 to 31 feet. Soil samples were obtained at 5-foot intervals by means of the split barrel sampling procedure in accordance with ASTM Specification D-1586.

*Sheila,
Proper
well
construction?*

The observation well materials included a 10-foot long section of 4-inch diameter PVC schedule 80 well screen with 0.010-inch slots. A Geotextile, Mirafi 140, was wrapped around the well screen to prevent intrusion of fines into the well. A riser pipe consisting of 4-inch diameter flush joint schedule 80 PVC pipe was used to extend the well to the surface. A 2 to 3 foot stickup was provided for all wells. Granular materials were placed around the well screens. After placement of a bentonite seal above the well screen, the borehole annulus was grouted around the riser pipe. After installation of the well in the borehole, the drill rod was placed inside the well pipe and the well casing was flushed with clean water, thus removing the bentonite drilling fluid. A 5-foot section of 6-inch diameter black protector pipe was then placed around the PVC pipe at each well location. The specific installation for each observation well is shown in Exhibit X, Page 23.

See Map Exhibit IV (back) for the location of Observation Wells 1-8
and 10. Observation Well No. 9 is ^{13,800 ft} 1300 feet north and west of Well No. 7,
on the line between NW 1/4 and SW 1/4 of Section 11, Township 59N, Range
19W, just east of the county road.

EXHIBIT IX

MINNTAC TAILINGS BASIN OBSERVATION WELLS - WATER ELEVATIONS - L.S. DATUM

Date/ Well No.	1	2	3	4	5	6	7	8	9	10
7/22/81	865.5									
7/23/81		859.5								
7/24/81			857.7	867.1						
7/27/81					873.3	858.6				
7/28/81							845.2			
7/29/81								877.0		
8/04/81										929.1
8/05/81									830.7	
9/25/81	865.5	859.3	857.5	866.6	872.2	858.2	844.2	875.8	829.4	925.8
12/21/81	865.4	859.3	857.5	866.8	872.4	858.5	844.5	876.4	829.7	927.0
4/30/82	865.6	859.3	857.3	867.0	872.5	858.5	846.6	876.9	830.6	928.2
7/29/82	865.7	859.4	857.6	866.8	873.3	858.5	844.9	876.8	830.5	927.9
10/21/82	865.5	859.1	857.5	866.7	873.8	858.2	844.9	876.5	830.7	928.4
5/12/83	865.7	859.3	857.7	867.0	873.9	858.6	845.1	877.0	830.3	928.4
7/26/83	866.1	859.4	857.7	866.2	873.2	858.4	844.6	876.9	830.2	929.0
11/1/83	866.0	*	857.8	866.8	873.7	858.5	845.2	877.3	830.4	928.3
6/22/84	866.0	859.7	857.7	866.8	874.3	858.6	848.4	877.7	830.8	928.9
10/22/84	866.4	859.8	855.8	867.1	873.4	858.5	846.3	876.9	830.1	927.4
5/21/85	866.3	859.6	857.7	867.1	873.4	858.5	846.0	877.7	830.7	929.1
8/27/85	866.4	859.8	858.0	866.5	872.9	858.5	845.3	877.5	830.1	927.2
11/8/85	866.4	859.8	858.0	867.0	873.6	858.8	844.9	877.2	830.5	928.6
7/16/87	865.8	860.0	858.4	866.4	874.6	858.9	848.4	877.9	830.0	927.1

1986 Data?
(wet year)
← 1987 was dry year

AVERAGES:

1981	865.5	859.4	857.6	866.8	872.6	858.4	844.6	876.4	829.9	927.3
1982	865.6	859.3	857.5	866.8	873.2	858.4	845.5	876.7	830.6	928.2
1983	865.9	859.4	857.7	866.7	873.6	858.5	845.0	877.1	830.3	928.2
1984	866.2	859.9	856.8	867.0	873.9	859.6	847.4	877.3	830.5	928.2
1985	866.4	859.7	857.9	866.9	873.3	858.6	845.4	877.5	830.4	928.3
1986										
1987	865.8	860.0	858.4	866.4	874.6	858.9	849.4	877.9	830.0	927.1

* Flooded beaver dam

UNITED STATES STEEL CORPORATION
MINNESOTA ORE OPERATIONS

Groundwater Observation Well Elevations & Locations

<u>Minntac</u>			
<u>Well #</u>	<u>Top of Casing Elevation</u>	<u>Ground Elevation</u>	<u>Co-ordinates</u>
1	872.0	869.4	21,794.6N/3,751.8E
2	862.3	859.5	23,109.2N/3,025.9E
3	864.4	862.6	23,760.2N/2,679.5E
4	871.6	869.0	32,036.0N/5,964.8W
5	876.4	873.8	31,717.0N/15,178.1W
6	863.6	861.1	28,852.0N/15,436.6W
7	851.2	849.2	23,048.5N/14,524.9W
8	883.0	880.6	17,572.5N/16,451.4W
9	836.1	833.7	25,785.6N/27,113.4W
10	935.4	933.5	18,673.7N/5,892.3E

Elevations are referred to Lake Superior Datum
at 602.0 feet.

JLC
8/18/81

PERIMETER DAM

The perimeter dam (see Exhibit XI, Page 26) consists of two parallel coarse tails shells with an impervious core of fine tails in between. Muskeg is removed from the original ground area to be occupied by the perimeter dam. a 10-foot key-way is dug into the underlying soil. The two coarse tails shells are then placed in 10-foot vertical lifts. The present (1987) top of dam elevation is 900 to 920 feet, Lake Superior Datum (1502 to 1512 feet M.S.L.).

Some sections have been completed to a 910-foot elevation. The present highest section of the perimeter dam is 70 feet, or seven 10-foot lifts. Due to the original ground topography, some sections of the dam still show original ground elevation above the present top of dam elevation.

All coarse tails are hauled from the plant site by haulage trucks and placed with the assistance of various crawler tractors, front-end loaders, and graders. The roadway width on top of the coarse tails shells is maintained at 100 feet, and the coarse tails angle of repose is 1V:1.5H. A 70-foot minimum distance from toe to toe between the coarse tails shells is maintained.

When the water rises to approximately 10 feet, the coarse tails edge slumps to a stable slope of 1:2 beneath the water. The coarse tails remaining above the water will still remain at 1:1.5 slope.

A pipe line grade is constructed on top of the safety berm on the core side of the outside coarse tails shell. Pipe is laid from the plant site to the perimeter dam area where the coarse tails shells have been constructed. Taps in the pipeline are placed at 120-foot intervals. This

work is in preparation of placing fine tails between the coarse tails shells to form the impervious core of the perimeter dam. Fine tails, at 50% solids, are pumped from the plant site. Depending upon the distance from the plant site, usually a 1,000-foot length of core area can receive fine tails at a time. Fine tails are placed in two 5-foot vertical lifts to equal the 10-foot lift of the coarse tails shells. As the fine tails reach the first 5-foot lift, the taps, or spigots, in that area are shut off and a different set of spigot further along the pipe line are opened. This jumping ahead continues until the entire length of core to receive fine tails during the current season has been raised 5 feet. The spigots back at the first area are then opened again for the second 5-foot lift. The same jumping ahead process is followed until the entire length has been raised a total of 10 feet. The two 5-foot lifts and the jumping ahead process allow the fine tails to de-water themselves. The water runs ahead of the area receiving fine tails and through the inside coarse tails shell back into the tailings basin, due to the existing core slope. Spigotting fine tails from the outside coarse tails shell allows the coarser particles to settle out and the finer particles to place themselves against the inside coarse tails shell. Spigotting occurs during the non-winter months only.

what's to prevent the water from draining thru outside coarse tails shell?

The entire dam perimeter construction process is quite lengthy. It can take three or more years to make one complete 10-foot lift along the entire 48,000-foot perimeter. It is presently planned to complete the entire dam to at least a 910 foot (L.S.) elevation. Perimeter dam construction higher than a 910 foot elevation will be contingent on a water discharge permit which could control the water elevation at 900 feet.

INNER CELLS

Intermediate, or inner, cells are constructed within the perimeter dam area relatively close to the plant site to contain the fine tails. It should be noted that the spigotting process described under "Perimeter Dam" utilizes only 10% of the total fine tails produced while spigotting is occurring. The inner cells are constructed of a single shell of coarse tails placed again by haulage trucks and various pieces of auxiliary equipment. An initial 10-foot minimum fill is placed to enclose a new inner cell. An over-flow culvert is placed at the opposite end of the inner cell from the inlet point. The inner cell would then be ready to receive fine tails. Fine tails flow from the plant site at a discharge elevation of 1,040 feet to the inner cells by gravity in slurry form via a system of open ditches or launders. The slurry is 50% solids, although miscellaneous plant floor wash water dilutes this somewhat. The launders either follow along the edge of the tailings basin or cut across existing inner cells. Launders have 10-foot wide bottoms and rock lined banks, and are designed at 0.8% to 1.0% slopes. Coarse tails shell elevations around an inner cell are maintained to accomodate the fine tails, which deposit themselves at a 0.4% slope and to maintain a 5-foot free board. Additional coarse tails are placed, as the contained fine tails elevation rises, in lifts of 10 feet, vertically following the inner cell perimeter center line. This is the center method of raising the inner cell perimeter. The fine tails settle out as the slurry flows across the area of the inner cell. Clear water then overflows through the outlet culvert, arriving eventually at the clear water cell for return pumping to the plant site.

The inner cell perimeter is not impermeable, although sealing does occur as the fine tails elevation rises. Some clear water does leave the inner by seepage through the coarse tails. The seepage is monitored and the occasional resulting sluffing repaired as needed. Inner cells are 200 to 400 acres in area and are mulched with hay and/or vegetated for dust control when inactive. A minimum number of cells are utilized at any one time as another effort in mitigating dusting potential.

Fine tails slopes are on a parabolic curve. Minntac known fine tails slopes of 10,000 feet to the water's edge averages are: 0.75% for 21% of the distance; 0.39% for 37% of the distance; and 0.28% for 42% of the distance.

Underwater slopes of fine tails is 3.5%. Very little of the fine tails migrate out to the flat ground contours. If the grade is greater than 1.5%, there is no settling out of the fine tails. With grades of less than 1.5%, the tendency is for the fine tails to flow to the water's edge then build back up the slope towards the discharge point.

The tailings basin is designed to handle the plant capacity of 18 million tons of pellets annually. The basin is currently handling the reduced annual operating level.

TAILINGS

A. COARSE TAILINGS

1. Size Gradation:

<u>Sieve No.</u>	<u>% Passing</u>
4	94-100
10	68
20	31
40	12
60	5
150	3
200	---

Size Range: -4 mesh to +200 mesh

2. 15% moisture

3. Handling specification: angle of repose 48 degrees.

4. 40% of total tails is coarse tails.

5. 28% of total crude is coarse tails.

6. Chemical Composition:

70% SiO₂
13% Total Fe
4% CO₂
3% CaO
2% MgO
3% H₂O
5% Miscellaneous

TAILINGS

B. FINE TAILINGS

1. Size Gradation:

<u>Sieve No.</u>	<u>% Passing</u>
20	100
35	95
65	85
150	75
270	65
325	60
500	45

2. 30% moisture in tailings in place.
3. Handling specifications - pumped at 50% solids.
4. Dry fine tails - specific gravity 2.87.
5. Chemical composition:

69% SiO₂
14% Total Fe
7% CO₂
4% CaO
3% MgO
2% H₂O

GROUND WATER FLOW SYSTEM

Ground water, in the basin, occurs within the geologic framework previously described. The water that enters the groundwater system is that which percolates through the taconite tails and the unsaturated glacial deposits (soil). Once the water reaches the zone of the bedrock, its course of movement is controlled by the fluid potential of the ground water. This potential is dependent, to a large degree, on the hydraulic conductivity of the geologic material and on the configuration of the water table.

A contour map of the water table, which is the upper surface of the zone of saturation, can be used to show the direction of water movement within the ground water system. Under natural conditions, the water table is a subdued image of the land surface; it is high under hills and low under depressions. Such a profile indicates that recharge occurs in local topographically high areas, and the discharge occurs in the adjacent lowlands, usually occupied by streams, lakes, or wetlands.

A water table contour map (Exhibit IV, back), was constructed for the Minntac Tailings Basin. Water elevations measured in the ten previously described observation wells (Exhibit IX, Page 22) were used as the base data. The elevations are Lake Superior Datum. The contours show the water occupying the east to west depression which the Dark River followed prior to the basin construction. The natural water flow of the Dark River has been intercepted by the Minntac Tailings Basin dike in the vicinity of Observation Well No. 7.

Recorded water level elevations, at the observation well sites between 1981 and 1987, show no change (Exhibit IX, Page 22).

Please refer to Exhibit IX, Page 22. The first number in each column is the static water level when each observation well was installed. Note the lack of water elevation change over the years. The basin water remains ponded up in the original washed glacial deposits of the Dark River channel.

If water were not constantly being withdrawn from the basin for taconite processing, the water level, in the basin, would approach a more level elevation.

Assuming the basin is a closed water system, pollutants in the plant-basin water have no access to the public waters. The natural water flow will bypass the basin facility. The co-mingling of natural and basin waters is not possible.

It is not a closed system; with seepage etc

Water seepage and the planned discharge of basin water will once again establish an expanded recharge source for the Dark and Sand Rivers. The major volume of discharged water will be controlled and divided into a particular river system. Overflow into the Dark River system would provide a natural water flow. A quick reference to the ground water contour map, Exhibit IV (back), indicates a natural drainage through the site of Observation Well No. 7.

← Not true

RATES AND DIRECTIONS OF GROUND WATER MOVEMENT

The following discussion concerns itself with the "natural" ground water movements in the area of the Minntac Tailings Basin. The basin was constructed as a "closed system." Water entering the basin is either lost by evapo-transpiration or collected in a clear water pond and recycled back into the plant site. Water motions within the basin are ← Dam Seepage man-controlled and have no effect on the area's ground water.

Refer to Chapter : Hydrogeologic Report of Surrounding Lands, Page 18, Number 4 of this report for the following.

"Cook-Embarrass Region:

The Cook-Embarrass Region lies between the Giants Range and the Vermilion moraine (pl. 1). From the south shore of Birch Lake past the south shore of Lake Vermilion, the moraine is the north limit of the region and is discernible on Plate 1 as a line of discontinuous ridges. Although the region is largely low and swampy, it is crossed by two east-west morainal ridges. The underlying bedrock surface is very irregular and crops out in many parts of the region. Glacial drift has filled bedrock lows lessening irregularity of the terrain.

Drainage is sluggish and swamps are large. The major streams draining the region include the Dark, Embarrass, Little Fork, Pike, Prairie, and Sturgeon Rivers. Several lakes are associated with the moraines..."

The original "natural" flow of water from the area of the basin was north-west down the Dark River. A minor original flow occurred north and east into the Sand River.

The outside report mentioned above, Page A18, records values for a survey station numbered 1310 on the Dark River. "Drainage area, 50.6 square miles...run-off for a 2 year recurrence interval is 0.089 cubic

feet per second per square mile (pre-basin). The Minntac Tailings Basin is intercepting approximately 20% of the Dark River Basin recharge. It is estimated, the water intercepted by the basin in the Sand River system would amount to 3% of volume at Pike River Gauging Station at Embarrass.

The internal tailings basin water flow consists of the following:

Storm water and runoff:	5100 gallons per minute	= 422,400 gal per day 7.3 mgd
Process Water for re-use:	45 - 50 mg per day	50 mgd
Sewer Plant water:	60,000 gallons per day	.06 mgd
Laboratory water discharge:	3,650 gallons per year	—
Dam seepage: To Dark River:	0.71 cfs	458,853 gal/day
To Sand River:	1.37 cfs	885,393 gal/day

Water seepage and the intentional discharge of tailings basin water will affect flow rates along the main drainage systems of both the Dark and Sand Rivers. Increased water flow can be expected throughout the year. Water discharge into the two-river system will maintain water flow during a dry season.

The increased artificial water flow, during freezing weather, will affect the ice cover and oxygen content of the river and lake waters along the main rivers' drainage systems. The latter condition should improve fish growth and lessen kill-off during the winter months.

Discharged water flow outside of the major river-lake channels should not be affected. Artificial, intentional discharge of tailings basin water will be irregular in volume and in its timing.

*about sev mil
about rate + direction
of flow*

INTERACTIONS: GROUND WATER AND SURFACE WATER

Much of this discussion has been covered in Chapters, Ground Water Flow System, and Rates and Directions of Ground Water Movement. The seepage and planned discharge of tailings basin water will cause recharge to the two rivers' (Dark and Sand) main streams depending upon engineered decisions concerning the need for discharge. The rate of taconite concentrate production, rainfall, seepage, pumping, and tailings displacement of water dictate the lack of, or overabundance of, process water contained in the basin.

It would be expected that the amount of ground water within the main river channels would remain about constant. Surface water will vary greatly with basin discharge operations.

Currently (1987), the average precipitation yield for the Minntac tailings basin is 5,224 GPM or 8,410 AF/YR. The planned discharge of basin water would vary from 0 to 6,000 GPM. The discharge timing would coincide with the high flow intervals of both river systems.

ANALYSIS: GROUND WATER QUALITY, SURFACE WATER QUALITY, &

WATER USERS - DISCHARGE OF BASIN WATER

Fluoride Reagents?

No harmful chemicals are contained in the basin water. An over-abundance of certain chemicals (exceeding the Minnesota Water Standards) would undoubtedly cause known and unknown problems. Water from the Basin will be diluted by natural surface and ground waters along the two (Dark and Sand) river systems. Filtration of seepage water through taconite (inert) tailings (sand and silt sizes) begins a reduction in the water's chemical content. 2. BRS

The slow passage of seep and discharged waters permits time for the water to interact with organic chemicals in the muskeg swamps along its passage downstream. Bacteria and organic matter will break down, for instance, sulfates. ("Domestic Water Treatment" p. 67, McGraw-Hill 1980.)

Water quality, in the vicinity of the tailings basin, will be affected. The distance from the basin to the nearest local inhabitant is relatively great. Minimum distances to habitations are: 1 mile north to Sand Lake; 5 miles northwest to Dark Lake; 3 miles east to Highway 53. Provided seepage is kept in check; the closer proximity of Sand Lake to the north is not a problem. The bedrock basin controls the surface and ground waters flows in a generally east-west direction. See Exhibit III.

The tannin content of the local lakes will be diluted and a clearer water will be noted with the infusion of low tannin content water into the system.

Water well water quality should not be affected. The great distance from the basin to domestic water well locations (nearest well is two miles) should provide enough surface water dilution to maintain water well water quality at the present (1987) level.

Ground and Surface Water in the Mesabi and Vermilion Iron Range Area Northeastern Minnesota

By R. D. CUTLER, H. L. YOUNG, L. R. PETRIE, and C. H. PRIOR

WATER RESOURCES OF THE MESABI AND VERMILION IRON RANGES

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1759-A

Prepared in cooperation with the
Minnesota Department of Iron Range
Resources and Rehabilitation



GROUND AND SURFACE WATER IN MINNESOTA

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GROUND WATER.

The chemical composition of ground water from municipal wells shows an average dissolved-solids content of about 230 ppm (table 7). The principal constituents of well waters are calcium, magnesium, and bicarbonate. Sulfate is present in significant concentrations in most well waters. The water generally is moderately siliceous, is hard or very hard, and contains much iron and manganese. Other dissolved constituents, such as sodium, potassium, chloride, fluoride, nitrate, and boron, occur in such low concentrations that they have little effect on the use of the water. The color of water from most wells is 5 units or less and for some is nearly zero. The turbidity in water from most wells is less than 2 units, but for a few it is between 20 and 30.

TABLE 7.—Chemical composition of untreated ground water used for municipal supply (1960)

[Results in parts per million except as indicated]

Constituent or property	Glacial drift (24 wells)				Biwabik Iron-Formation (15 wells)			
	Maxi- mum	Mini- mum	Aver- age	Per- cent ¹	Maxi- mum	Mini- mum	Aver- age	Per- cent ¹
Silica (SiO ₂).....	33	13	21	9.0	26	4.1	14	6.4
Iron (Fe).....	10	.04	1.9	.9	4.9	.05	.82	.4
Manganese (Mn).....	5.5	.00	.83	.3	1.8	.00	.35	.2
Calcium (Ca).....	90	20	52	20.3	76	18	45	20.6
Magnesium (Mg).....	48	8.9	19	7.7	36	6.6	18	8.2
Sodium (Na).....	3.1	2.6	5.8	2.4	12	4.1	7.1	3.3
Potassium (K).....	3.3	.6	1.8	.7	5.8	.9	2.1	1.0
Bicarbonate (HCO ₃).....	413	102	220	43.5	333	94	219	48.6
Sulfate (SO ₄).....	88	3.8	34	13.4	88	2.0	23	10.1
Chloride (Cl).....	12	.0	3.5	1.5	12	.0	3.0	1.1
Fluoride (F).....	.3	.0	.2	.1	.2	.0	.1	.0
Nitrate (NO ₃).....	1.6	.0	.5	.2	7.1	.0	.9	.2
Boron (B).....	.11	.00	.04	.0	.09	.01	.06	.0
Dissolved solids.....	477	127	253	-----	396	104	213	-----
Hardness as CaCO ₃	420	87	212	-----	339	72	191	-----
Noncarbonate hardness as CaCO ₃	-----	-----	32	-----	-----	-----	11	-----
Alkalinity as CaCO ₃	339	84	180	-----	273	77	180	-----
Percent sodium.....	-----	-----	6	-----	-----	-----	8	-----
Specific conductance (micromhos at 25° C.).....	758	178	408	-----	648	162	372	-----
pH.....	7.8	6.5	7.4	-----	7.8	6.8	7.4	-----
Color (units).....	130	0	10	-----	5	0	2	-----
Temperature (°F).....	49	42	45	-----	50	43	45	-----

¹ By weight of dissolved solids.

EVALUATION OF EXISTING WATER QUALITY MONITORING SYSTEM

All natural waters contain dissolved mineral matter. The quantity of dissolved mineral matter in a natural water depends primarily on the type of rocks or soils with which the water has been in contact and the length of time of contact. Ground water is generally more highly mineralized than surface runoff because it remains in contact with the rocks and soils for much longer periods.

The water contained within the tailings basin was originally surface runoff and bedrock water co-mingled. This natural water has been altered by additions of other ions during its passage through the taconite process.

In general, the quality of "...ground water from the Biwabik Iron Formation and from the drift is similar. The water is generally moderately siliceous, hard or very hard, and contains much iron and manganese. Surface water is generally soft, contains much iron, and is highly colored..."¹. More iron is found in surface water.

The present water quality monitoring program utilizes the above described ten observation wells, in addition to samples of the Dark and Sand Rivers, and water samples from within the basin.

Water samples are analyzed for the following: pH, total hardness, total alkalinity, dissolved solids, specific conductance, nitrates, sulfates, total iron, dissolved iron, manganese, dissolved manganese, total lead, and amine. The latter is introduced into the process water during flotation concentration of taconite concentrates.

The water quality monitoring system currently being employed on the Minntac property is accurate, up-to-date, and providing the local and area-wide data concerning the basin operation.

Under this permit, no piezometers or additional monitoring wells will be required.

A series of cross-sections located around the tailings basin were requested by letter dated October 5, 1987 to Mr. P.X. Masciantonio of USX from the MPCA.

Much of the indicated land is not owned or controlled by USX. The preceding discussions apply to these lands as well as the basin. The surrounding lands are composed of swampy topography with glacial debris and bedrock comparable to the basin materials.

The shallow surface, only slightly masking the bedrock surface, supports a water system described within this report.

No additional dikes, dams, mine tailings, seepage control or hydraulic relief structures are present.

No geophysical measurements have been made on these lands.

The water flow is to the northeast and to the northwest. A general east to west direction is controlled by the bedrock surface.

The water table is surface to near-surface as indicated by swamps and shallow lakes.

¹ Ground and Surface Water in the Mesabi and Vermilion Iron Range Area
Northeastern Minnesota - Water Supply Paper 1759-A, Page A1.

